Laser spectroscopy of neutron-rich copper isotopes

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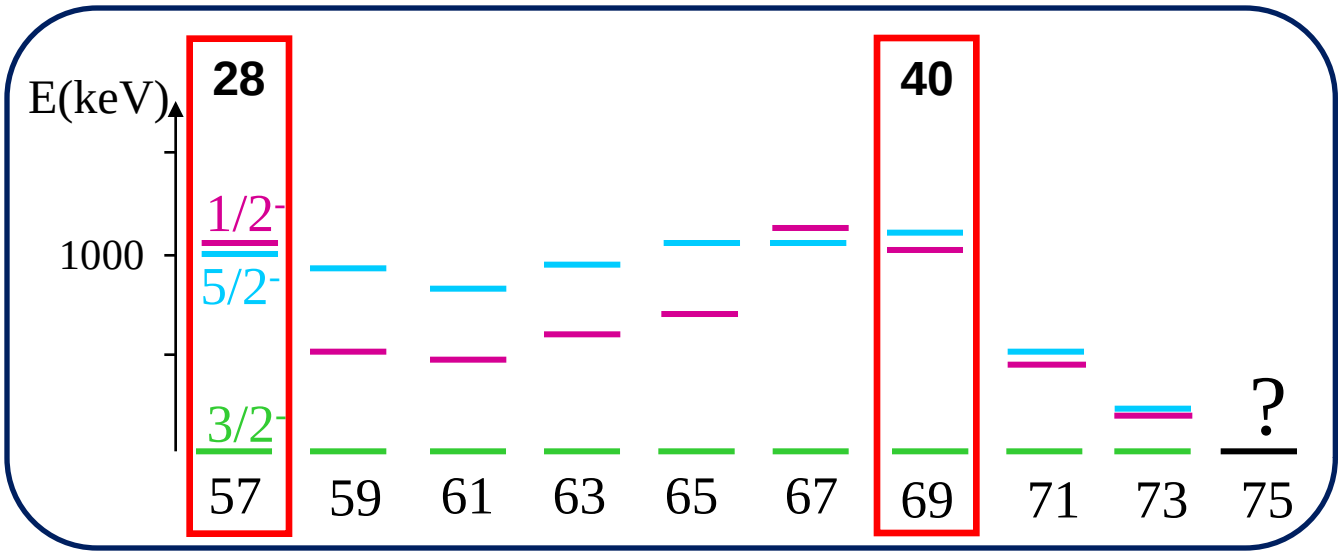
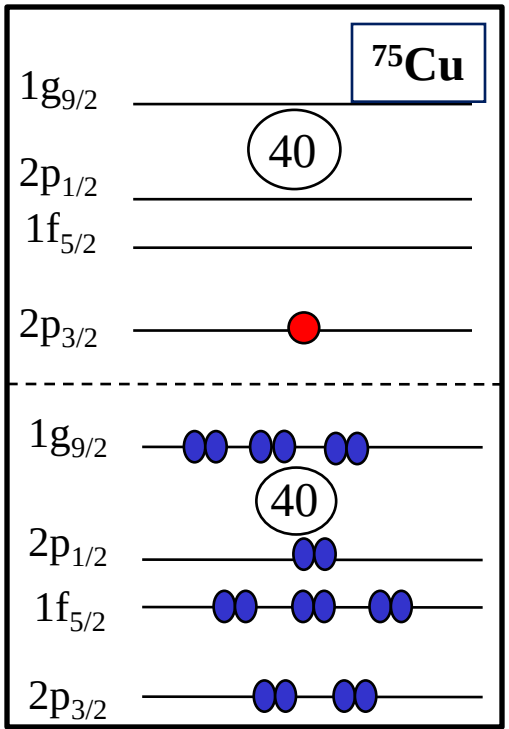
15/06/2009

Motivation: The region of the nuclear chart

	28												40									50	
	Zn 57	Zn 58	Zn 59	Zn 60	Zn 61	Zn 62	Zn 63	Zn 64	Zn 65	Zn 66	Zn 67	Zn 68	Zn 69	Zn 70	Zn 71	Zn 72	Zn 73	Zn 74	Zn 75	Zn 76	Zn 77	Zn 78	Zn 79	Zn 80	30
Cu 55	Cu 56	Cu 57	Cu 58	Cu 59	Cu 60	Cu 61	Cu 62	Cu 63	Cu 64	Cu 65	Cu 66	Cu 67	Cu 68	Cu 69	Cu 70	Cu 71	Cu 72	Cu 73	Cu 74	Cu 75	Cu 76	Cu 77	Cu 78	Cu 79	29
Ni 53	Ni 54	Ni 55	**Ni 56**	Ni 57	Ni 58	Ni 59	Ni 60	Ni 61	Ni 62	Ni 63	Ni 64	Ni 65	Ni 66	Ni 67	**Ni 68**	Ni 69	Ni 70	Ni 71	Ni 72	Ni 73	Ni 74	Ni 75	Ni 76	Ni 77	**Ni 78**	28

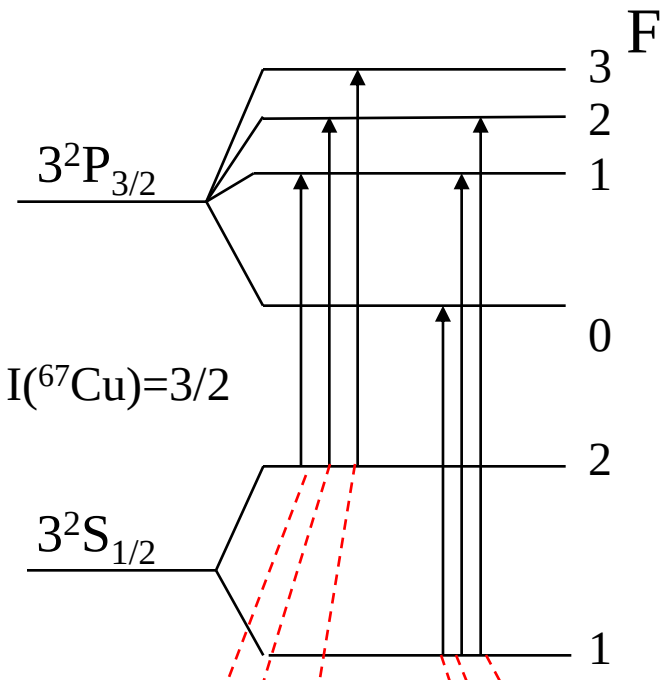
$\nu 2p_{3/2}$ $1f_{5/2}$ $2p_{1/2}$ $\nu 1g_{9/2}$ gets filled





Franchoo et al. Phys.Rev.C. 2001, Stefanescu et al, Phys.Rev.Lett. 2008

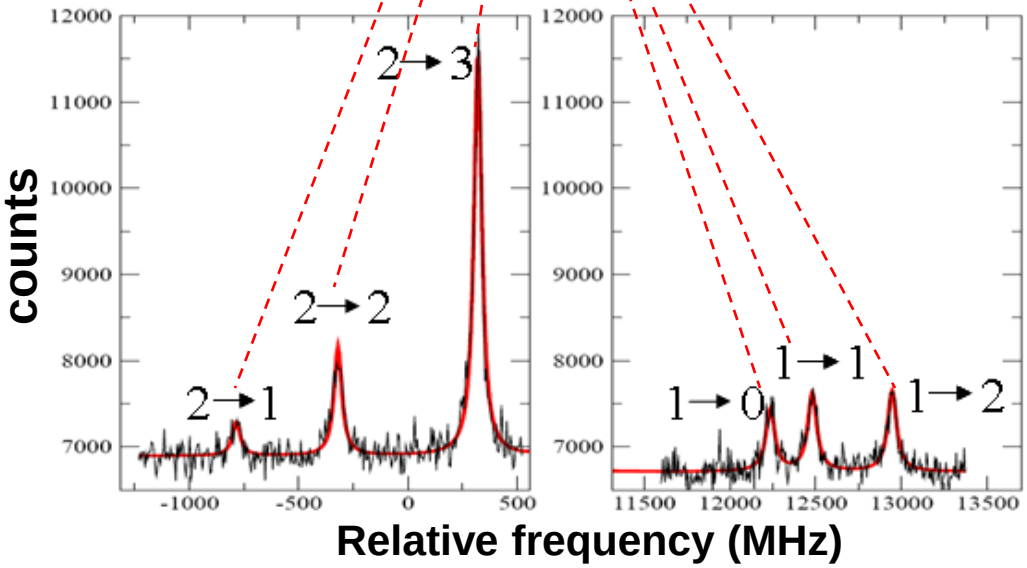
Laser spectroscopy: experimental technique



F=I+J

$$\Delta E = \frac{1}{2} AC + B \frac{(3/4)C(C+1) - I(I+1)J(J+1)}{2I(2I-1)J(2J-1)}$$

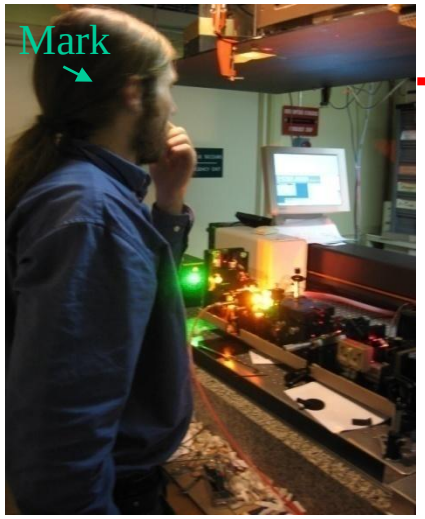
$$C = F(F+1) - I(I+1) - J(J+1)$$



$$\mu_I = \frac{AI}{A_{ref} I_{ref}} \mu_{ref}$$

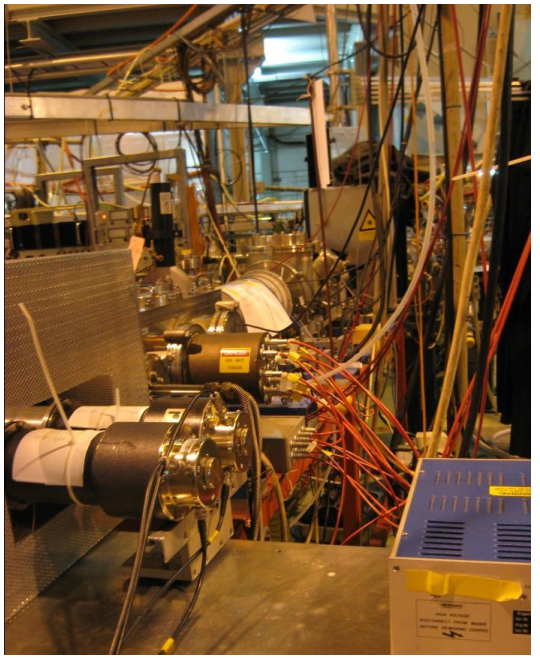
$$Q = \frac{B}{B_{ref}} Q_{ref}$$

Laser spectroscopy: experimental setup



Dye laser

Wavelength 648nm,
Doubled to 324nm



mirror

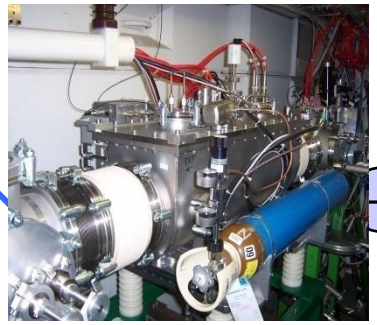
Post-acceleration voltage

charge exchange
Cell (200°C)

Photomultiplier tubes

electrostatic
deflectors

Ion beam



From HRS

RFQ beam cooler/buncher

Accumulation time: 5-100ms
Bunchwidth: 25μs

Varying post-acceleration voltage to scan frequency:

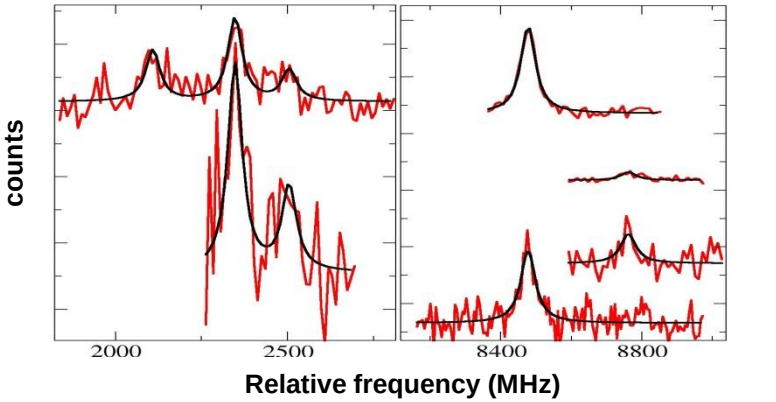
$$\nu_{laser} = \nu_{transition} \frac{1 \pm \beta}{\sqrt{1-\beta^2}}$$

$$\beta = \sqrt{1 - \frac{M_0^2 c^4}{(Uq + M_0 c^2)^2}}$$

^{72}Cu: spin confirmation of 2, a challenge for nuclear shell model

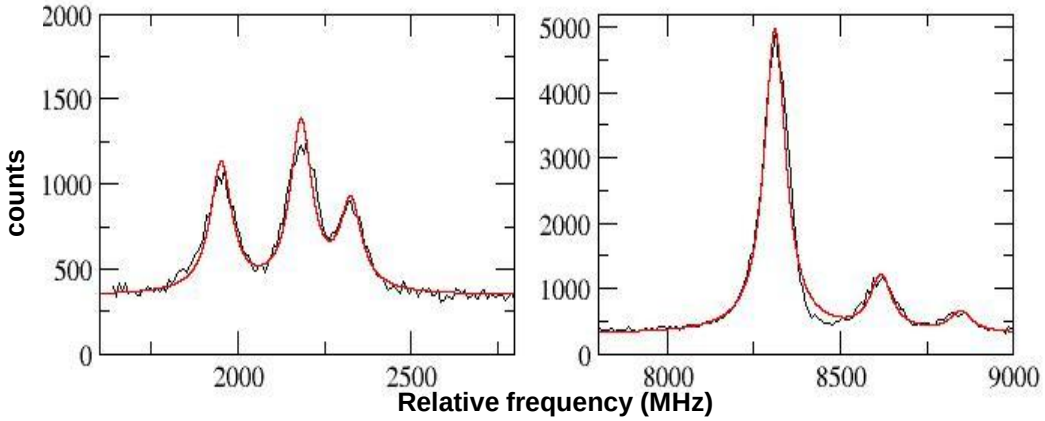
2007, without RFQ beamcooler

K. Flanagan



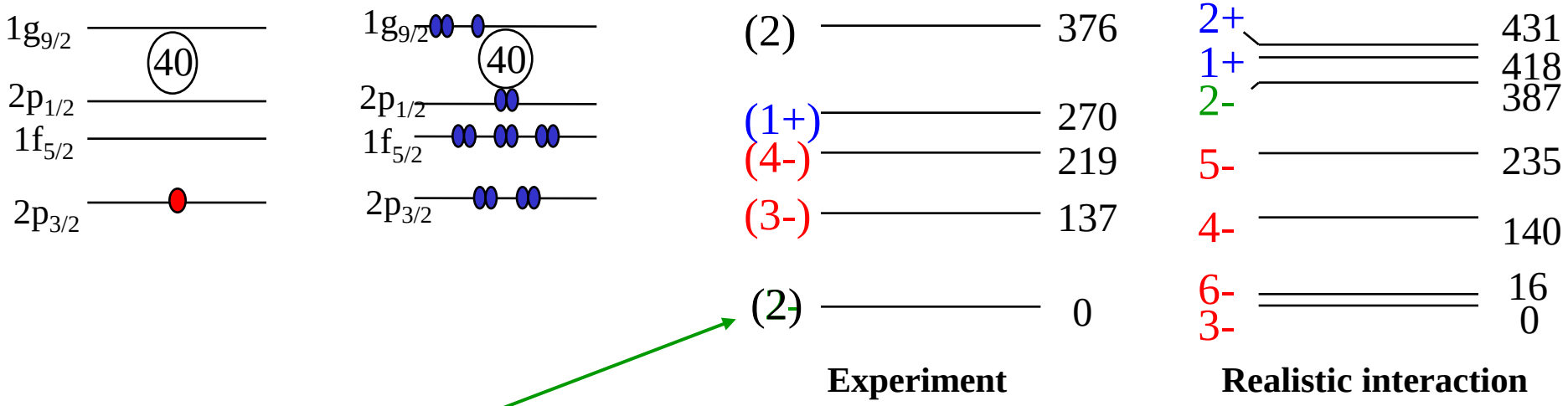
>40 hours measured, 5 out of 6 peaks resolved

2008, with RFQ beamcooler



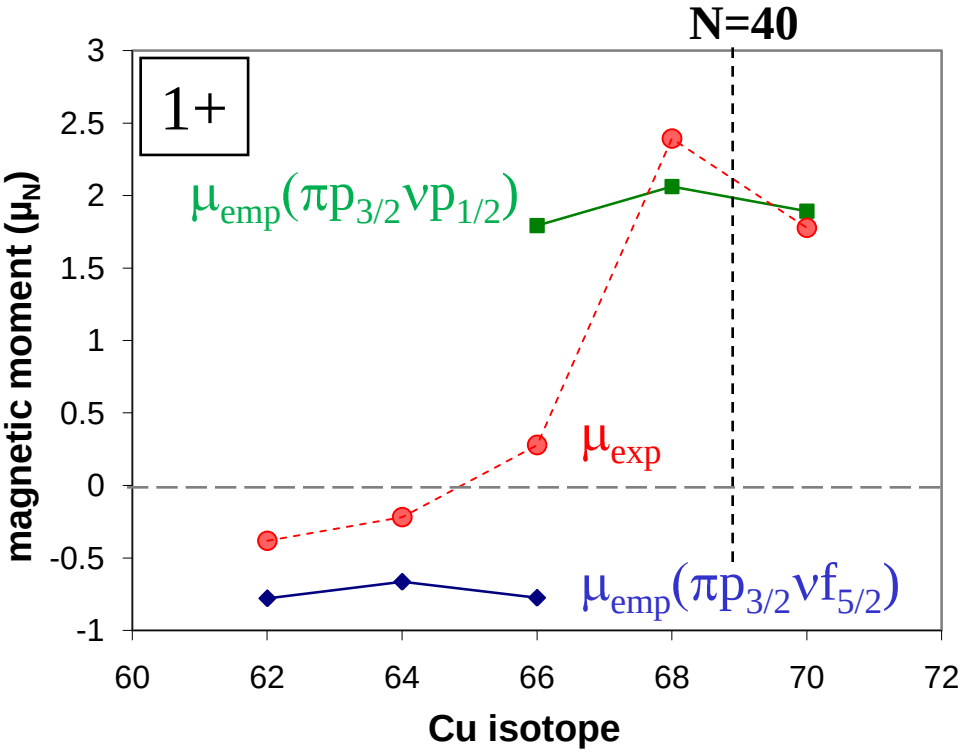
2.5 hours measured, 6 out of 6 peaks resolved

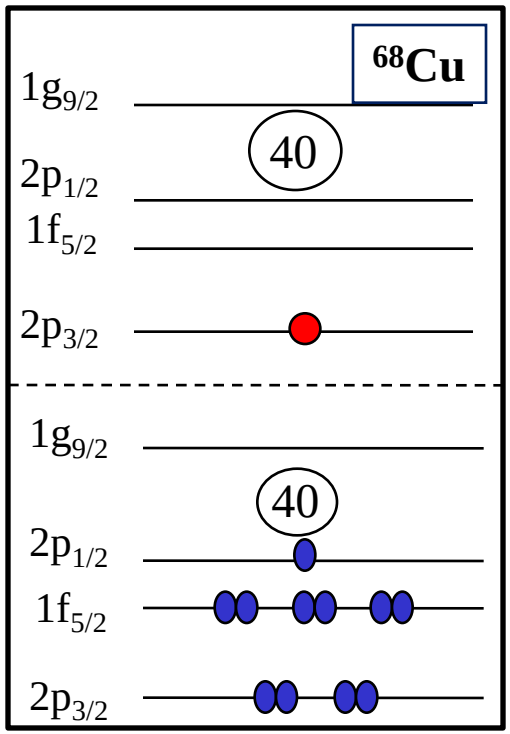
^{72}Cu: spin confirmation of 2



J.C. Thomas, Phys.Rev.C 2006

Evolution of the 1+ magnetic moments



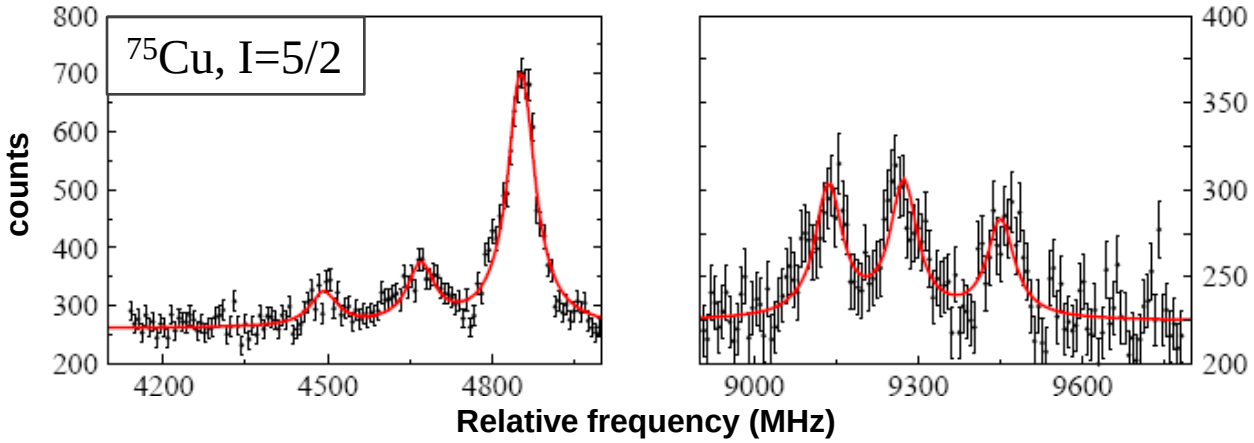


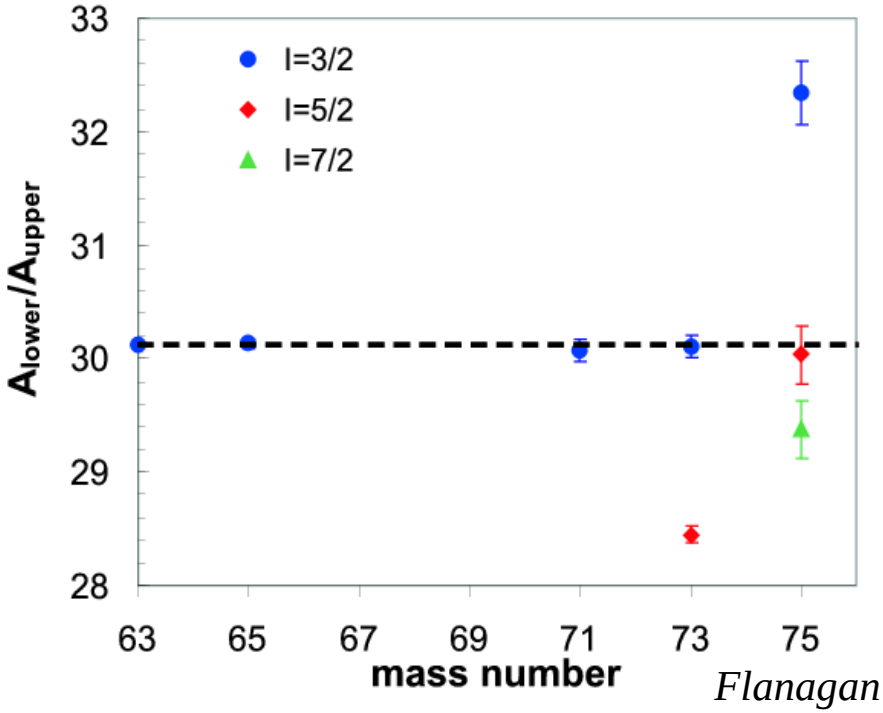
For ^{68}Cu: $\mu_p=\mu(^{69}\text{Cu})$
$\mu_n=\mu(^{67}\text{Ni})$

Assume weak proton-neutron coupling:

$$\mu(I) = \frac{I}{2}\left[\frac{\mu_p}{j_p} + \frac{\mu_n}{j_n} + \left(\frac{\mu_p}{j_p} - \frac{\mu_n}{j_n}\right)\frac{j_p(j_p+1) - j_n(j_n+1)}{I(I+1)}\right]$$

^{75}Cu: Spin assignment





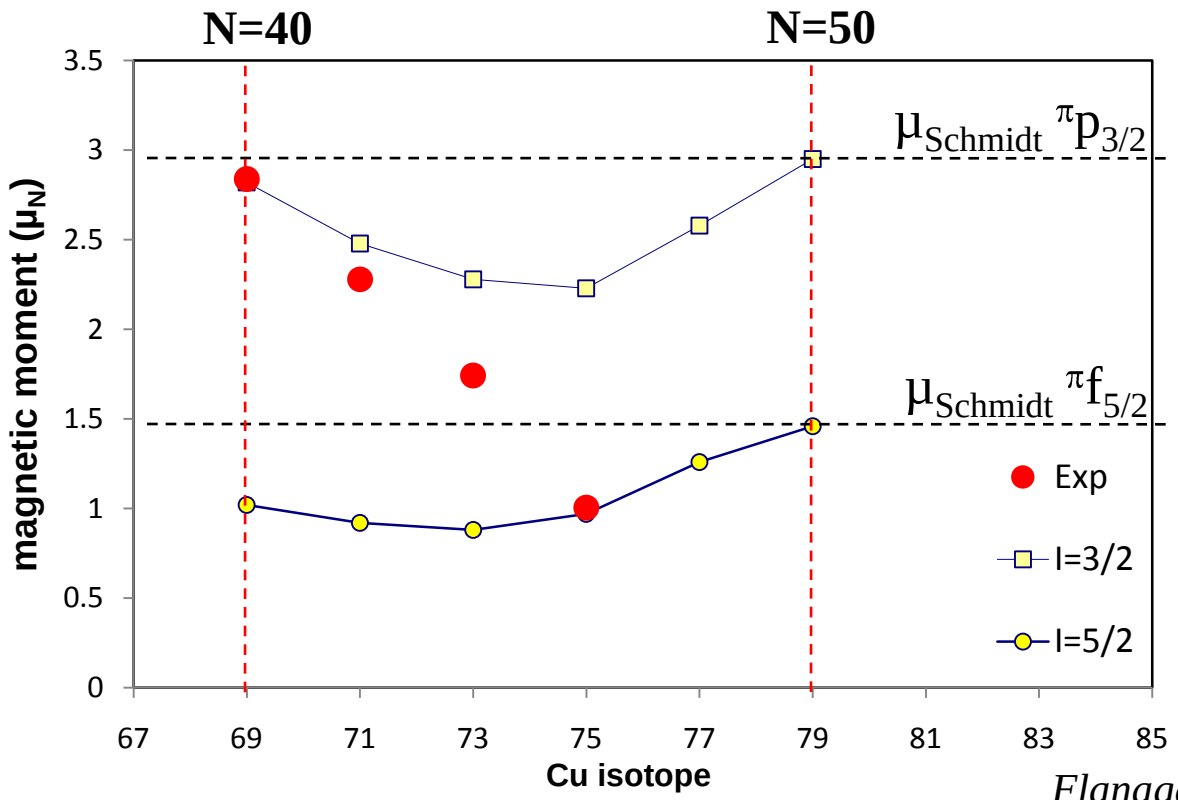
- Yield ~ 5 10^4 ions/μC
- Accumulation time 100ms
- Background reduction of 10^3

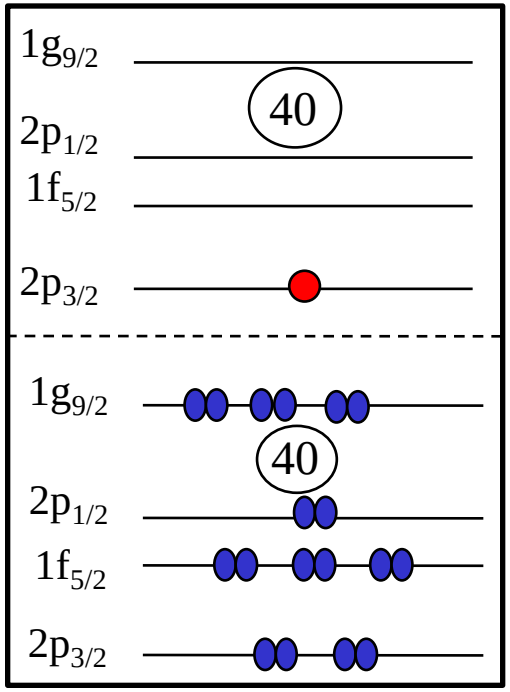
A ($^2S_{1/2}$) = +1592(1) MHz
B($^2P_{3/2}$) = -34(2) MHz

SPIN OF 75Cu IS 5/2

Flanagan et al., in preparation

Comparison odd magnetic moments with theory





Flanagan et al., in preparation

Model space: $1f_{5/2,}$ $2p_{3/2}$, $2p_{1/2}$, $1g_{9/2}$ for both proton and neutron orbits, 56Ni core

Interaction: jj4b, by Brown and Lisetskiy(private communication), by varying two-body matrix elements and single particle energies to fit 400 experimental binding and level energies in this region.

Conclusions and Outlook

Conclusions

• The copper isotopes ^{61}Cu - ^{75}Cu have been measured at COLLAPS, ISOLDE. During the 2008 experiment 11 isotopes were measured.

• Background reduction of 10^3 and more due to the RFQ beam cooler/buncher allows measurements on more exotic isotopes.

• The results obtained reveal important structural information in this region and contain several challenges for theoretical models.

Recent and future experiments

• Neutron-rich Ga isotopes (E.Mane, B.Cheal) (May 2009)

• Isotope shifts of neutron-rich Mg isotopes (September 2009)

• Collinear Resonant Ionization Spectroscopy(CRIS) on francium isotopes.

• 9 shifts of beamtime left on neutron-deficient Cu isotopes (2010+)

The Collaboration

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THANK YOU !

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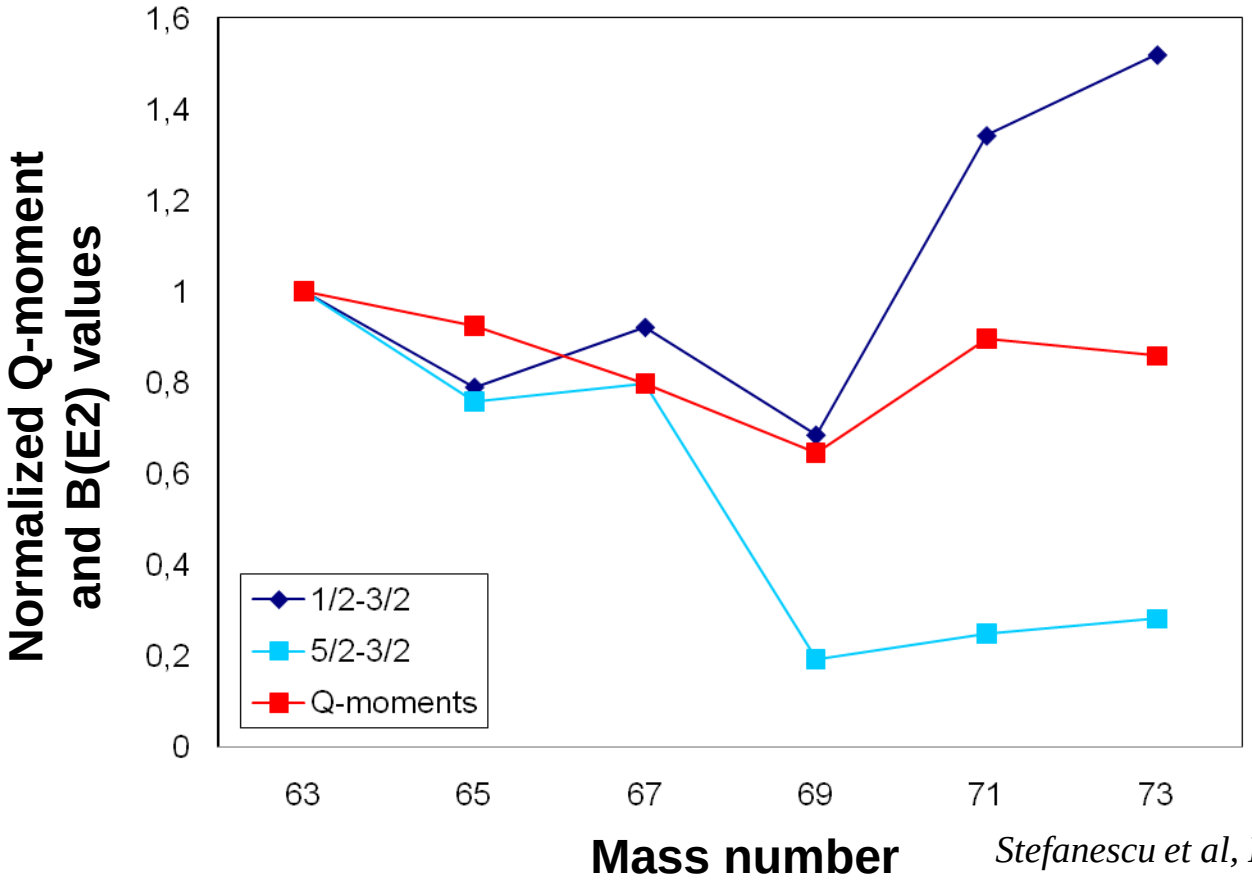
Quadrupole moments vs B(E2) values



Stefanescu et al, Phys.Rev.Lett. 2008

Minimum at N=40, but the ground state quadrupole moments don't suggest an increased collectivity beyond N=40.